TECHNIQUE OF MULTIBEAM BRIDGE SPAN AEROELASTIC OSCILLATIONS SUPPRESSING

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In contemporary bridge building in connection with the wide use of bridges with the large spans, very sensitive to different dynamic loads and those subjected to aeroelastic instability, arose the need for research and development of the designs of diverse suppressors of oscillations, and also methods of their calculation.

Aeroelastic oscillations present problem from different points of view: the main thing – this is the danger of the destruction of construction or appearance of fatigue failures. Problems are also discomfort for the people, sensitivity to the vibration of some types of equipment.

Basic target of the vibration shielding of constructions – reduction in the amplitudes of oscillations and, correspondingly, stresses in their elements, caused by the action of the dynamic loads of different nature. The amplitude of oscillations depends both on the parameters of load and from the dynamic properties of construction – natural frequencies and dissipative characteristics.

At the basis of different methods and means of oscillations extinction the aerodynamic, mechanical, combined principles can lie, the active and passive systems for control can be used. At the basis of mechanical methods lies a change in the natural vibration frequency of construction (due to increase in the hardness, change in the design scheme, etc.), increase of the damping properties of construction as a whole, and also the attachment of additional masses by means of the elastic and damping connections with the properly selected parameters. It is possible to note the following basic mechanical methods: Tuned Mass Dampers (TMD), viscoelastic dampers, liquid dampers.

We will examine in more detail the aerodynamic methods of the extinction of oscillations.

The problem of the guarantee of aeroelastic stability in the foreign bridge building is solved, in essence, in two ways [10]. One of them, that was called in the literature name “American”, is connected with an increase in the bending and torsional stiffness of construction. Another – “European”, is connected with the searches for such design forms, which would be characterized by good aerodynamic properties.

As one of the effective aerodynamic methods of the extinction of oscillations, caused by wind action – is design of the cross sections of elements and construction as a whole with the streamlined form, when the insignificant destabilizing nonstationary forces, which specify the aerodynamic instability of construction, does not appear [1, 2, 10].

The selection of the streamlined form of structural cross-section is most expedient to carry out at the stage of design. Giving this form to the already operable construction, which manifest aeroelastic instability and which have the bluff form, is achieved by the installation of the fairings about different types.

The cases of the installation of fairings on the bridges across river of Yamato (Japan), St John (USA) rivers, through Long Bays and Lion Gates (Canada) and others are known, whose effectiveness was preliminarily evaluated during the experimental wind-tunnel investigations, and then confirmed under actual operating conditions [3, 8, 9]. The construction of triangular fairing with the great lengthening proved to be most effective from the point of view of aeroelastic oscillations amplitudes reduction. However, the wide use of fairings as the method of the extinction of oscillations, is limited by their excessive material consumption.

Another aerodynamic methods for prevention of the bridges oscillations, in particular which consist of two or more main beams, arranged in parallel, should be considered the selection of the distance between the beams, with which the construction possesses more favorable aeroelastic

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Abstract

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properties. Experiments show [7] that, other conditions being equal, there are ranges of a change in the geometric parameters of the multi- beams systems, in which the constructions are subjected to the excitation of aeroelastic oscillations greater or lesser. Especially this is actual for the relatively narrow beams. Nevertheless, one should recognize that the selection of the geometric layout of the bridge construction is achieved on the basis of the deep technical and economic analysis of different factors, but not only from the aerodynamic considerations.

The aerodynamic methods of oscillations decreasing based on a number of known effects, such as a circulation control of the wind current around the elements of construction, or creation of phase displacement in the detachment of Karman's vortices from different sections along the construction length, i.e., attenuation of correlation between the pulsations of speed.

In the literature, for example, the method of a reduction in the pulsating loads, which act on rectangular prism, is described by action on the flow detached from its surface with the aid of small cylinder [5]. During the specific mutual arrangement of prism and cylinder the pulsation factor of lift decreases more than by an order. This action is achieved by an installation of small circular controlling cylinder from one side of prism. The experimental data about a change in the flow forces and frequency of vortices in the dependence on arrangement and diameter of the controlling cylinder are obtained.

The effective decrease of aeroelastic oscillations can be reached with the aid of other mechanisms of action on the flow, for example by the creation of ducts or by the perforation of beams solid walls or of flooring. Ducts in the form of the rectangular slots, located near the edges of construction, prevent the action of vortices on tail end of the construction, decreasing thus the amount of periodic transverse force and the intensity of vortex excitation [1].

The effectiveness of the perforation of the walls of main beams was demonstrated with the study of the aerodynamic methods of the extinction of the oscillations of the bridge across river of Yamato (Japan), St John (USA) rivers, through Long Bays and Lion Gates (Canada) and others [3,8,9]. It was established that the making of cuts and slots in the roadway of the beams of bridge constructions, and also clearance between the flooring of roadway and the stiffening girder considerably increases the aerodynamic stability of suspension bridges.

For example, making aerodynamically transparent flooring made it possible to avoid aeroelastic instability of the galloping type of the suspended passages of the gas pipe with span 720 m through Dnepr river [10].

At the department of aerohydrodynamics of NSTU carried out the cycle of the works, in the process of fulfilling which the reasons for the excitation of oscillations were investigated and aerodynamic extinguishers for four real bridge spans were developed. Work experience and survey of literary sources show that the regular periodic gathering of two-dimensional vortex sheet from the surface of the bluff beams is the basic reason for the oscillations of similar constructions (and its interaction with the beams, arranged further downstream in the case of multi-beams constructions).

On the basis of understanding physical nature of the excitation of oscillations reached are formulated the basic principles of their aerodynamic suppression – formation of such flow pattern, with which clear peak on the spectrum of the pulsations of the speed and pressure in the environment of body will be washed away (i.e., it will be excluded or is considerably weakened the periodic vortex formation, which causes the alternating pulsations of pressure), the correlation of the pulsations of aerodynamic force along the length of structure is weakened, the possibility of existence of the multivariance of the structures of flow is removed.

Besides this basic principle, devices for the suppression must satisfy the following requirements:

- high effectiveness in entire range of possible wind speeds;
- the maintaining the vibration damping properties in any directions of the wind (hence follows the need for the symmetrical arrangement of devices relative to the construction of bridge span);

- an insignificant increase in the drag force of construction for the elimination of the onset of oscillations in the horizontal plane;
- the absence of static lift component at the zero angle of attack for the elimination of the bouncing of construction at horizontal gust of wind;
- minimumly possible overall dimensions and weight of devices, as the considerable weight increase of a bridge span constitution is intolerable because of hazard of static overload of facility;
- devices should not be cause of dangerous pressure oscillations;
- the devices not should hamper process of mounting (it is necessary to take into account, that the mounting of a bridge span is conducted by a method of a longitudinal travel and the bottom faces of beams are shaded slide on paths of rolling);
- the guarantee of a technological effectiveness during production and installation of devices.

The optimization of the geometric parameters of devices for suppression of oscillations by calculated methods today runs into the insurmountable difficulties; therefore the basic method of solution of this problem should be considered testing of models in wind tunnel.

For example, in the first stages of work at the suppression of the oscillations of Barnaul bridge [6] was checked the effectiveness of known devices for the aerodynamic extinction of oscillations (Byrd's spoilers, the perforated coatings so forth.) on the three-beams span. Experiments showed their low effectiveness - the amplitude of oscillations decreased not more than two.

Attempts of suppression of periodic departure of vortexes by the installation of devices of the different form in places of appearance of disturbances (the neighbourhoods of a forward stagnation point, corners of beams) nor have yielded of success.

During further examinations on damping aeroelastic oscillations of multibeam constitutions the devices consisting of three standard components, having a conditional title "spoiler", "plate" and "deflector" were designed (Fig. 1).

The spoiler declines downwards flow detached from upper edges forward streamwise of a beam. Thus the structure of flow becomes one-alternative and the periodic departure of vortexes of a miscellaneous sign on a site “maintained” by a spoiler is eliminated.

As the spoilers subject to a considerable wind loading and noticeably increment drag, the unjustifiable increase of their sizes can create oscillations of span in a horizontal plane.

Therefore during experiments the optimum installation sites ensuring minimum sizes of spoilers were determined at decreasing oscillation amplitude more, than on the order.

The spoilers are established with gaps, at the expense of it the misalignment of the vortexes departure moment lengthwise beams is reached.

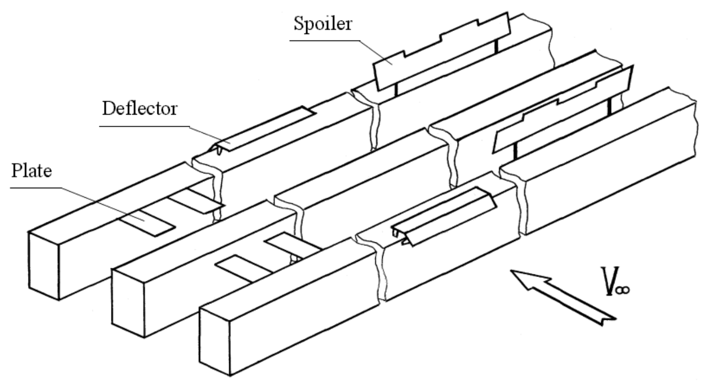

Fig. 1. Standard devices for damping of aeroelastic oscillations

For spoiler was not by a sourse of vortex structures, he has a variable width, which one is ensured with rectangular fingers on the upper edge. The declination of a spoiler in relation to a vertical is picked from reasons of security of equality to null of static component of lift.

The spoilers in themselves largely reduce

oscillations, however their effectiveness considerably will increase in case of application in a complex with plates or deflectors.

Plates represent a number of plates arranged horizontally in an interspace between beams. They render particular damping effect at heave of a construction, creating a great many of three-dimensional vortex structures.

The shared use plates with spoilers has allowed on the order to lower oscillation amplitude of a three-beam constitution of the bridge in Barnaul city.

However application of this pair of devices on model of the Tomsk bridge has shown their poor effectiveness, though difference between these bridges only in relative distance between beams.

The deflectors were set on exterior edges of extreme beams vice-versa of interspaces between spoilers. Their operation was exhibited in forcing down of a jet to a least upper bound of beam, than also attenuation of periodic vortex generation (and connected with it of pressure oscillations) is reached.

Attractions of deflectors is their compactness and small drag, however application of its devices is isolated (even in case of the installation on all length of a beam) not always reduces in satisfactory results in damping of oscillations.

Often joint application of deflectors with spoilers is the most effective version, for example such combination of devices more than on the order has reduced oscillation amplitude of the Tomsk bridge (Figs. 2 and 3).

As common singularity of aerodynamic methods of damping of oscillations, apparently, it is necessary to consider selectivity of their effect on configuration items of the particular geometrical form, therefore to apply them it is necessary very cautious.

Therefore, if any devices for damping aeroelastic oscillations have shown earlier high performance on similar, but a little distinguished constructions, all of them equally should necessarily subject to careful experimental checkout on models in wind tunnels.

For today theoretical definition of optimum geometrical parameters of spoilers, plates, and deflectors such as a breadth, slope angle, the excess above a surface of a beam and other is not obviously possible, a large volume of parametric examinations therefore should be carried out, by results of which one the best version will be selected.

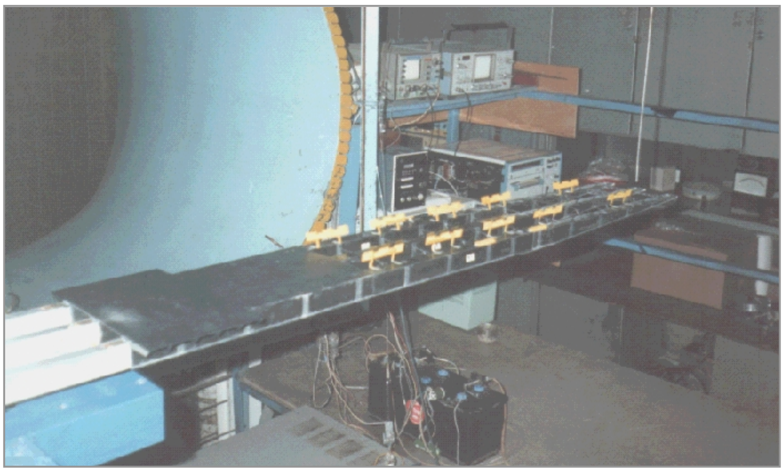

Fig. 2. General view of the Tomsk bridge model in wind-tunnel

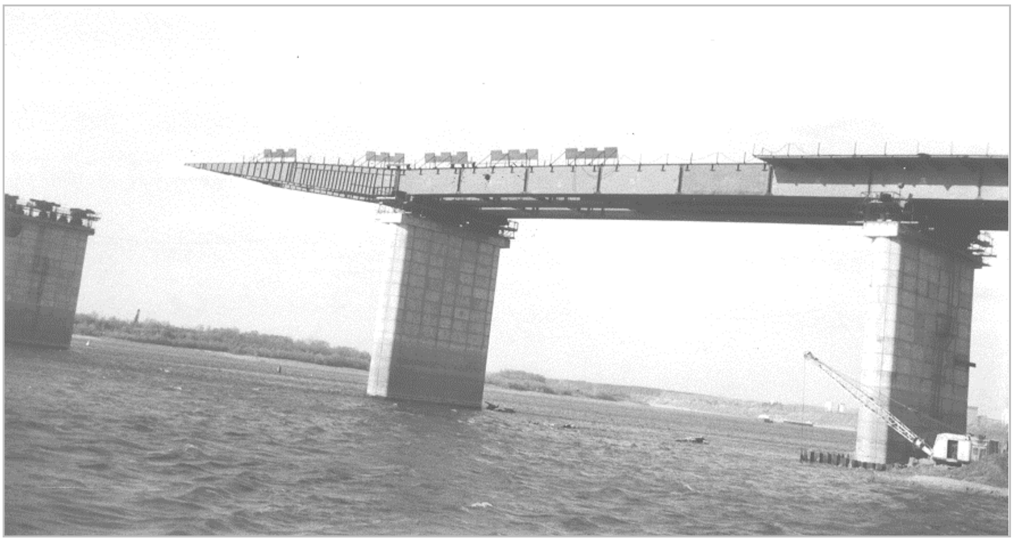

Fig. 3. General view of the full-scale Tomsk bridge with dampers

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